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Gas removal system associated with dredge pumps, Phase C, September 1967

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GAS REMOVAL SYSTEM ASSOCIATED WITH DREDGE PUMP: PHASE C

Status Report No. 16

Prepared by
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Prepared for
U. S. Army Engineers District, Philadelphia
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Philadelphia, Pennsylvania

September, 196[illegible]

Bethlehem, Pennsylvania

Fritz Engineering Laboratory Report No. 310.20

CIVIL ENGINEERING DEPARTMENT
FRITZ ENGINEERING LABORATORY
HYDRAULIC AND SANITARY ENGINEERING DIVISION

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PREFACE

The following status report summarized the progress made under Phase C of the project during the period April 1, 1967 to August 31, 1967, at the Hydraulic and Sanitary Engineering Division of the Fritz Engineering Laboratory, under the terms of Contract No. DA-36-109-CIVENG-64-72. The progress on the study was reported in fifteen status reports dated February 1964, April 1964, October 1964, December 1964, January 1965, June 1965, August 1965, October 1965, December 1965, February 1966, June 1966, August 1966, October 1966, December 1966, and April 1967. (Fritz Engineering Laboratory Report No. 310.1(1)*, No. 310.2(2), No. 310.4(3), No. 310.5(4), No. 310.6(5), No. 310.8(6), No. 310.9(7), No. 310.10(10), No. 310.11(11), No. 310.13(13), No. 310.14(14), No. 310.15(15), No. 310.16(16), No. 310.18(17), No. 310.19(18)). In addition, a translation (Fritz Engineering Laboratory Report No. 310.17) was prepared of an article entitled, "Wear Phenomena in Centrifugal Dredge Pumps" by A. Welte.

Phase A and Phase B of the project were completed and summarized in Fritz Engineering Laboratory Report No. 310.3(8) (June 1964), and No. 310.7(9) (February 1965) respectively.

Dr. John R. Adams is the project director. He is assisted by Mr. S. Ko and Mr. R. Miller, Research Assistants. Dr. L. S. Beedle is Acting Chairman of the Department of Civil Engineering.

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*Numbers in parenthesis refer to references on pages 11 and 12.

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I. Re-evaluation of Test Series No. 1 and No. 2

In response to questions by the sponsor about the conditions at the suction side of the pump the air percentages were recalculated at the pump suction face. From pressure readings in the accumulator the air percentage is nearly the same from the accumulator to the pump impeller. Thus the volumetric air flow rate at pump suction pressure is representative of the air flow rate for some distance along the suction pipe.

As these calculations were being done, two computational errors were discovered. No consideration of the portion of the area occupied by the air had been made in computing velocity heads. Since the suction velocity head is subtracted from the discharge velocity head, the change in velocity head is generally less than 10% of the total dynamic head for this pump setup. Also, for high air contents where the neglect of the air volume has a significant effect the velocity heads are low since the total flow rate has dropped by a large amount.

The second computational discrepancy is in the use of pressure heads in feet of water. Correctly applied in the energy equation, the local unit weight of the mixture should be used. This places a large emphasis on the assumption of a homogeneous mixture of air and water. The change in total head values is small, but the trend in the data is changed significantly. With reference to Fig. 1 in Status Report No. 14[17], the original calculations show both the head and discharge falling off as the air flow increases. When the correct velocity heads and pressure heads in terms of the mixture unit weight are used the head remains constant for suction air percentages less than approximately 9%.

Figure 1 shows the same data as Fig. 1, Status Report No. 14[17] and Fig. 1, Status Report No. 15[18] but with the head calculated using corrected velocity heads and pressure heads in terms of the mixture unit weight and with air percentages given for the pump suction pressure. Note the trend in the test points with increasing air volume as mentioned above. Also note that the air percentages are approximately twice the previous values. The air percentage shown is equal to the volumetric air flow rate at pump suction pressure divided by the volumetric water flow rate. The original air percentages were given by the volumetric air flow rate at standard conditions ($70^{o}F$, 25 psia) divided by the water flow rate. The discharge pressure is such that the air percentage at the magnetic flow meter is very nearly the same as that found for standard conditions.

From this data Fig. 2 was determined as a significant description of the "break point" as exemplified by the curves in Fig. 3. A graph of dimensionless head versus air percent shows a sharp drop near 9 percent air for most tests. In Fig. 2 this point is shown for all tests in which the break point was reached and for which the suction air percentage has been calculated. Thus for air volumes less than 9 percent of the liquid flow rate no drop in pump head is observed. Also, to this point, the water flow rate has decreased less than 10 percent, as may be seen in Fig. 1. However an increase in air volume to about 12 percent of the water flow results in a sudden drop in both head and water discharge. These drops are approximately 20% in head and 10% in discharge

(20% and 15% from no air flow). The operating conditions between these two air percentages are very unstable. This is true for most test runs with air percentages above 9 and is the reason for few and widely spaced points at high air contents.

If air is encountered in amounts which result in less than 9 percent air at pump suction, dredging production will be only slightly decreased with no danger of complete stoppage. It is likely that intermittent, short bursts of higher air volume may be handled with only momentary decrease in production. However, any gas removal system should be capable of reducing air flow through the pump to less than 9 percent of the liquid flow rate. This defines a minimum performance for gas removal systems. It may also pose a new question: What portion of the suction pipe may be filled with gas during dredging? This volume is needed to properly size the gas removal system.

A draft of the report summarizing the results of Test Series No. 1 and No. 2 has been completed and is being reviewed. The movies from these tests have been spliced. A commentary to accompany the movies will be prepared and included in the report.

II. Study of Air Injection

As decided in May and June, 1967, the distribution of air in the water is being studied. A possible explanation of the negative results of Test Series No. 2 on the effectiveness of the gas removal system is that the air flow was not properly modeled. The air was injected through 16 small orifices distributed evenly around the circumference of the inlet to the drag arm. This resulted in many small air bubbles moving with nearly the same speed as the liquid. The air-stream tended to rise to the top of the drag arm, but was dispersed through the entire area of the horizontal suction pipe by the secondary flow following the elbow. At higher flow rates the tendency to rise in the inclined portion of the pipe was diminished by the rapid motion.

There is a good possibility that a prototype dredge would encounter gas in a manner which would result in occasional large slugs of gas in the drag arm. This is quite different, even if several slugs are encountered at once, from the continuous, steady flow of fine bubbles obtained in Test Series No. 2.

The first modification of the air injection technique was a change in the number, size, and location of injection ports. The possible choices were: (1) fewer small orifices, (2) fewer larger orifices, or (3) single larger port in center of pipe. The third scheme was considered a limiting condition and was tried first. Figure 4 shows the piping arrangement. Both 1/2 inch pipe was 3/4 inch pipe were tried. Neither produced slug flow at any initial pumping rate or with steady or manually pulsed air flow. The air streamed from the injection tube in a single stream but had been broken into fine bubbles dispersed throughout the flow before it could be observed in the plastic suction pipe.

Observation of this scheme indicated that no arrangement of inlet ports would give slug flow with the air control valve located outside the tank. Automatic valves of pressure relief type were considered, but their response was too slow to give compact slugs.

Next a complete innovation was developed. Air filled balloons are lowered into the inlet to the drag arm where a spike punctures the balloon. (See Fig. 5 for a sketch of the pulley system used to lower the balloons). This does give good slug type air flow. At the present time no quantitative measurements are possible. However, the system shows some promise. At water flow rates of 400 gallons per minute a considerable portion of the air does rise into the accumulator. Medium speed movies were taken of flow in the inclined portion of the suction pipe and at the accumulator. However, the motion is too fast for this type of movie.

III. Future Plans

The timing necessary to take high speed movies of the slug flow from the balloons will be worked out and several high speed films taken. These will then be compared with several high speed movies of the air flow from the original injection system.

A mechanically operated valve on a small receiver tank at the center of the suction pipe will be constructed and tried. This has promise of more flexible operating sequences than the balloons on a cable as well as some opportunity for quantitative measurement.

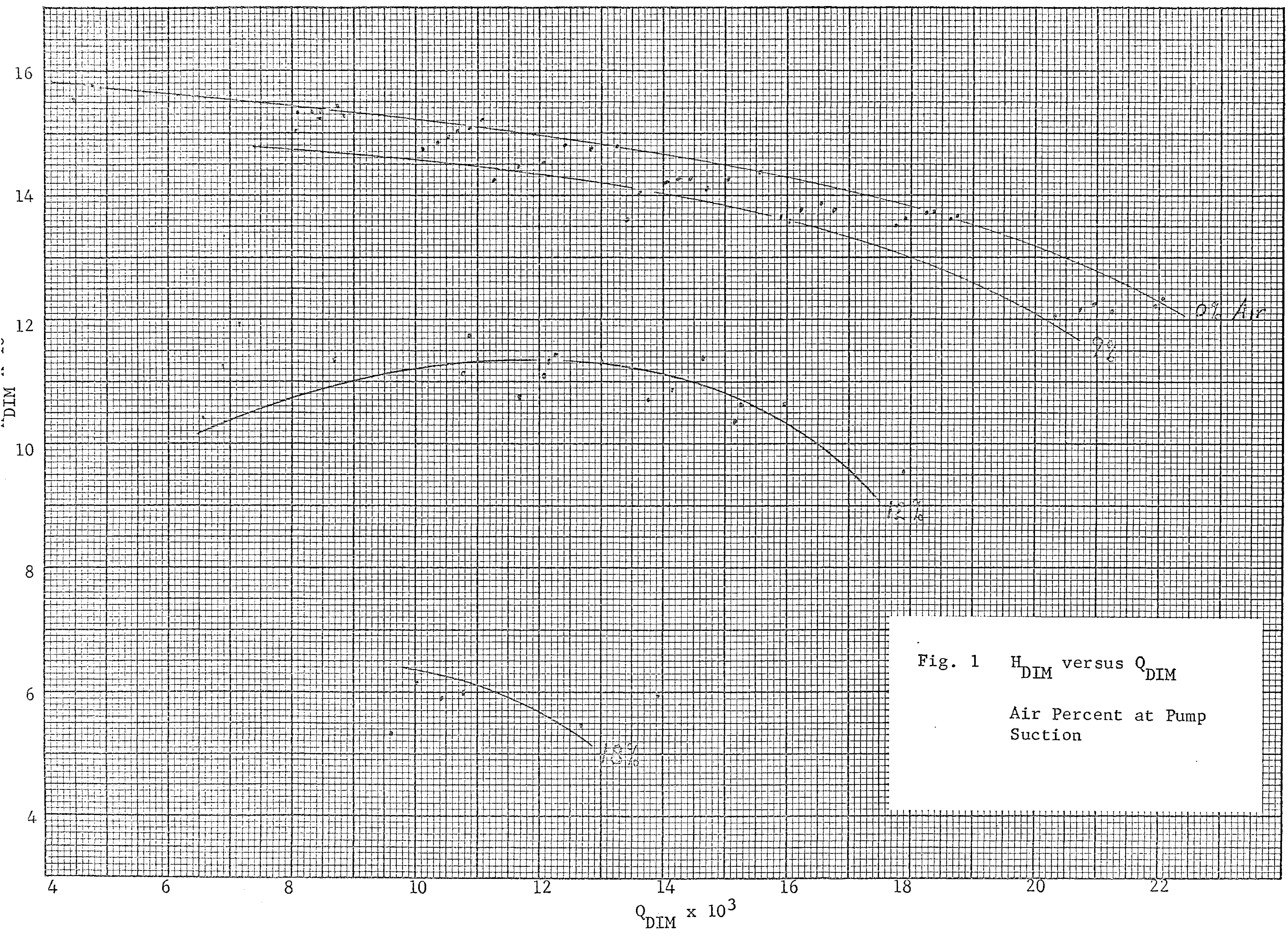

Fig. 1 H_{DIM} versus Q_{DIM}

Air Percent at Pump Suction

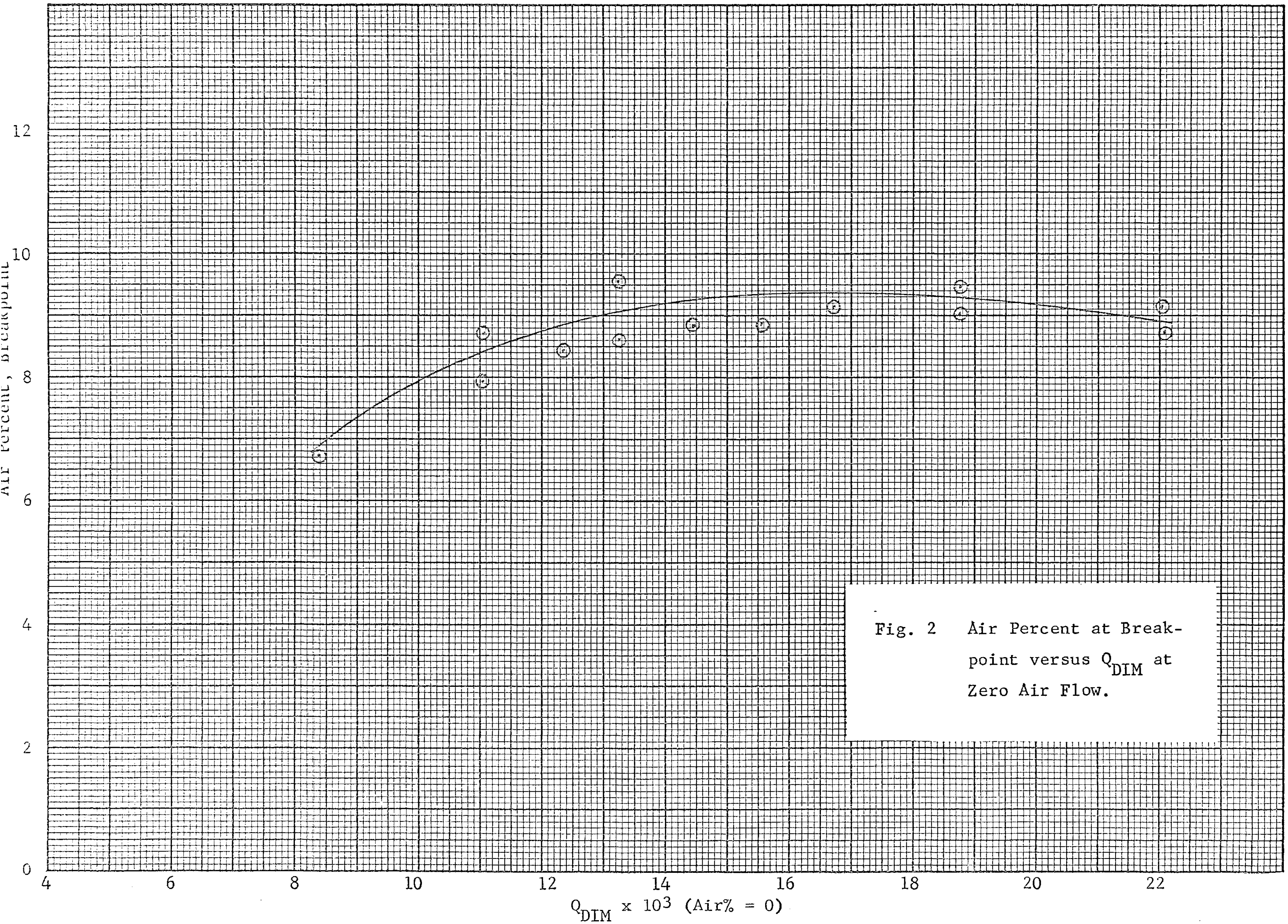

Fig. 2 Air Percent at Breakpoint versus Q_{DIM} at Zero Air Flow.

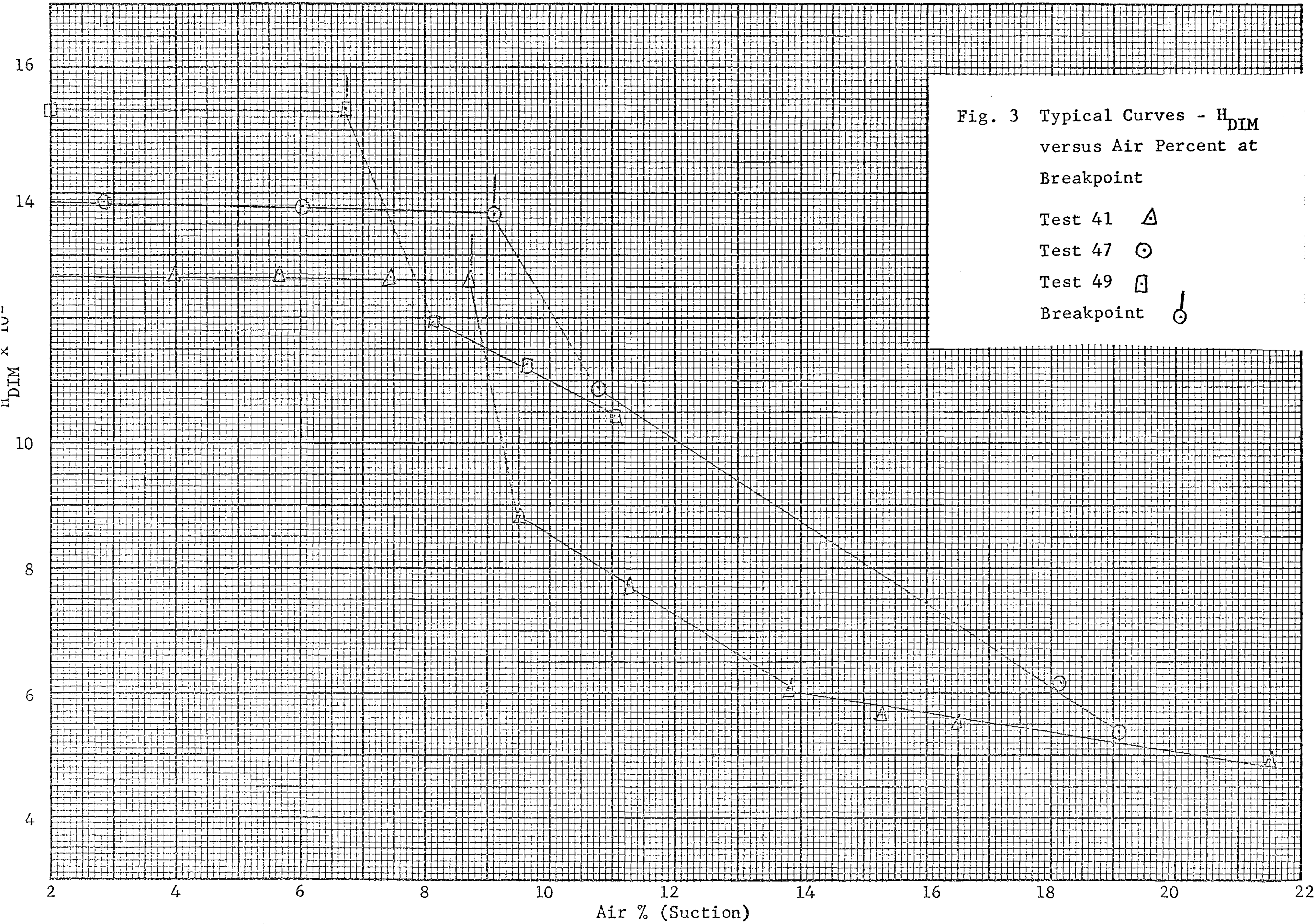

Fig. 3 Typical Curves - H_{DIM} versus Air Percent at Breakpoint

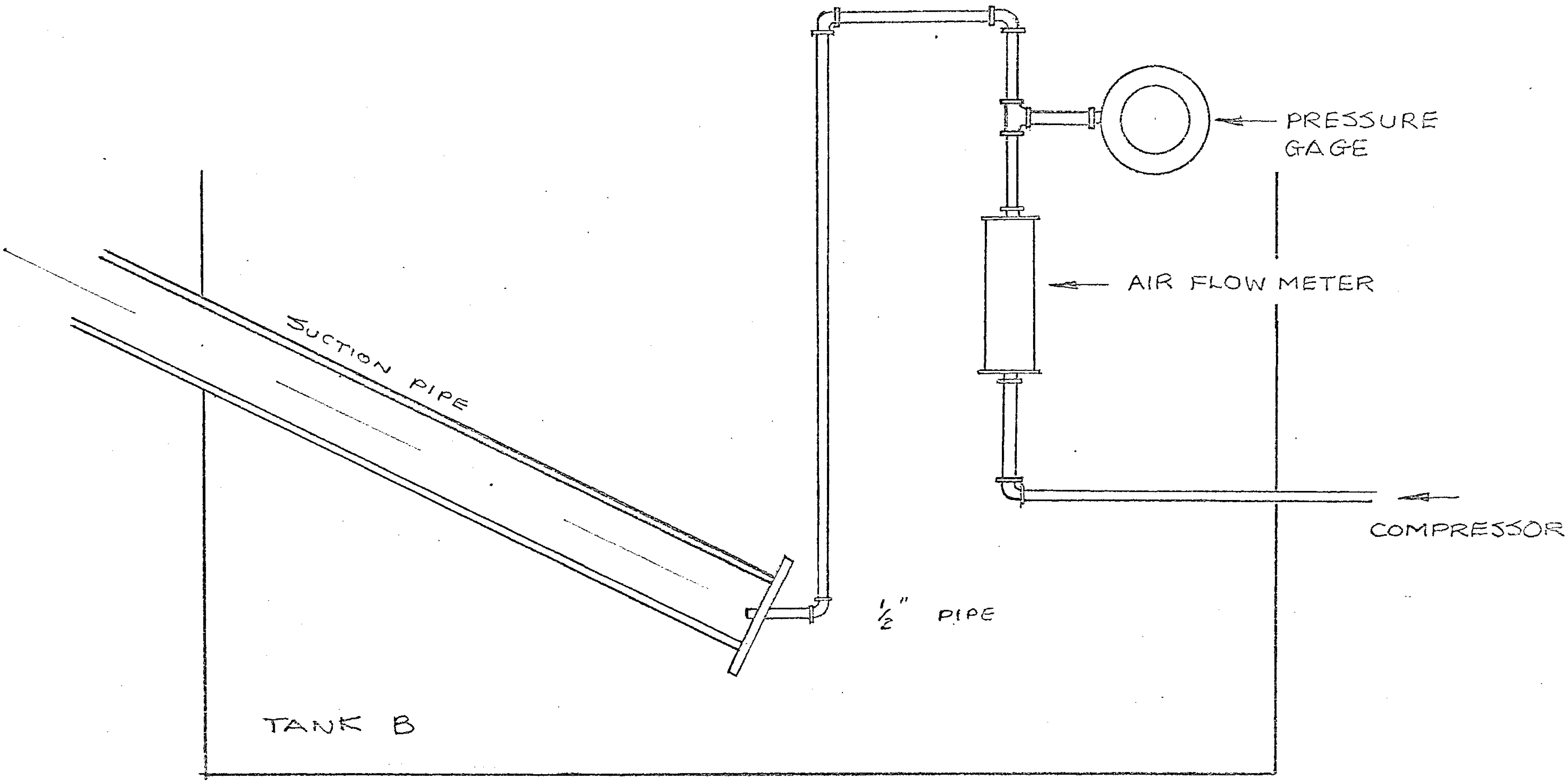

Fig. 4 Sketch of Single Port Injection System

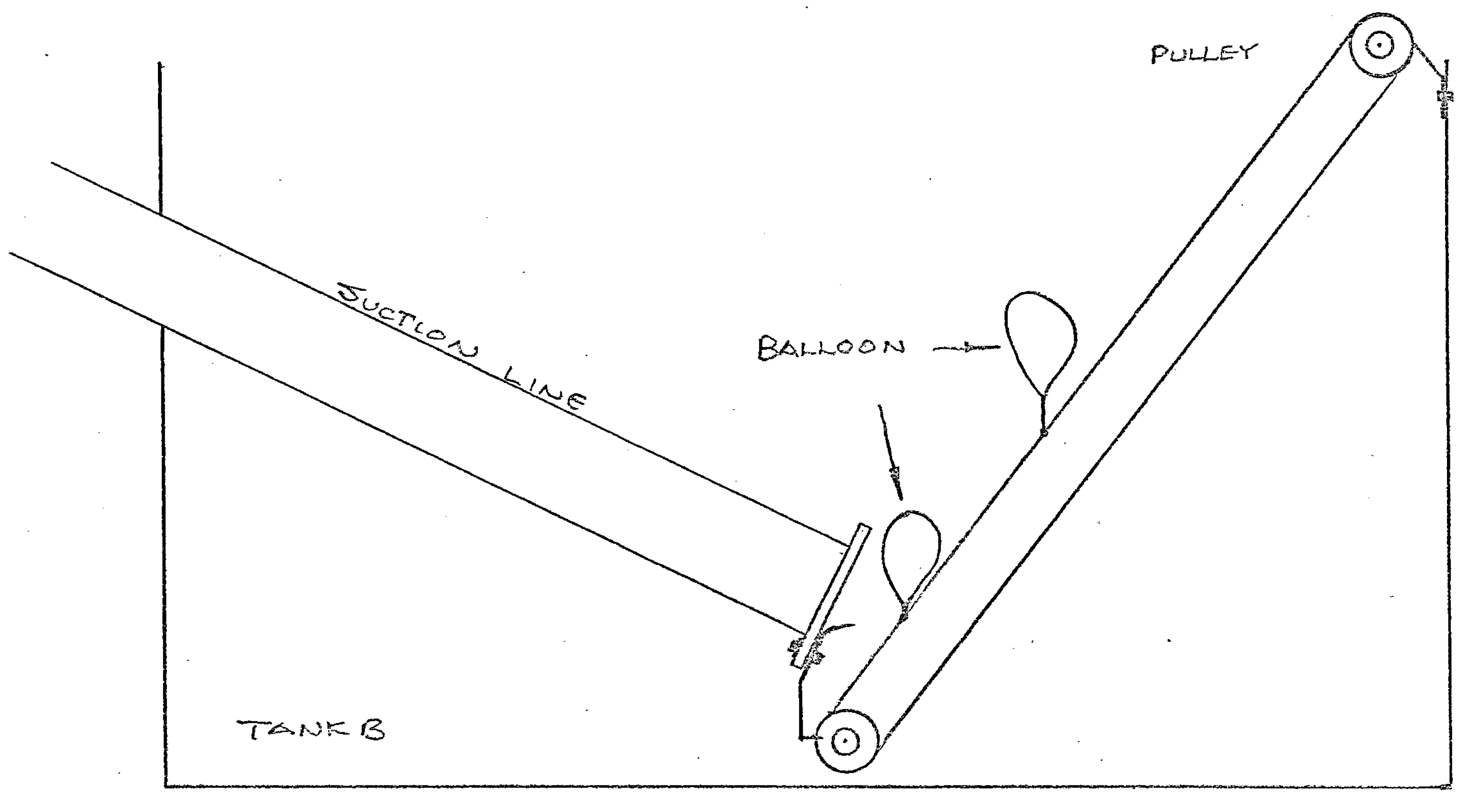

Fig. 5 Sketch of Balloon Apparatus

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